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Associations between off-label feed additives and farm size, veterinary consultant use, and animal age

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Abstract

Data from the United States National Swine Survey collected by the National Animal Health Monitoring System were used to describe the use of feed additives in swine feeds. Data were collected from 710 farms. The concentration of feed additives expressed in grams per ton of complete feed was described by stage of production, and the use of feed additives above the labeled treatment levels (i.e. off-label) was identified. Of the 3328 feeds, about 79% contained feed additives used in the labeled manner. For all classes of pigs, the prevalence of labeled feed additive use was greater than 75%. Penicillin was used according to its label most often, followed by apramycin, bacitracin, tetracyclines, lincomycin, and tylosin. Carbadox had the highest prevalence of off-label use. Of the 699 feeds that included feed additives in an off-label manner, about 57% included additives at greater than the recommended concentrations or were fed to an incorrect class of pig. About 56% of the feeds had off-label combinations of additives. Small farms were more likely to use rations with no feed additives than intermediate or large farms ($P < 0.001$). Of those farms using feed additives, the odds of a small farm using all feed additives in the labeled manner was 7.7 times that of an intermediate or large farm ($P < 0.0001$). After controlling for herd size, producers who used a veterinary consultant were 2.1 times more likely to use feeds with feed additives ($P < 0.0001$). © 1997 Elsevier Science B.V.

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1. Introduction

Consumers are concerned about the potential health effects of residues of antibiotics and sulfonamides and of antibiotic-resistant bacteria resulting from the use of feed additives to produce animals and animal products for human consumption (Elder et al., 1993; Sundlof, 1993; Begley, 1994; Berger et al., 1994a; Kunesh and Zimmerman, 1994; Phillips, 1994; Waltner-Toews and McEwen, 1994). There has been pressure from several consumer groups to restrict the use of penicillin, tetracyclines, sulfonamides and the newer classes of antibiotics such as fluroquinolones in animal agriculture based on perceived human health concerns (Elder et al., 1993; Berger et al., 1994a; Kunesh and Zimmerman, 1994; Phillips, 1994). However, sulfonamides and antibiotics reduce the costs of production by increasing the average daily gain and decreasing total feed requirements per pound of weight gained (Henry and Upson, 1992; Berger et al., 1994a). These are relatively inexpensive to use and of significant importance in the cost-efficiency of farm operations. Because feed accounts for 68% of the total cash expense in a farrow-to-finish operation, a reduction in the feed:gain ratio is economically justified (Berger et al., 1994a). These feed additives may also reduce risks of production by decreasing the probability and severity of disease outbreaks, controlling subclinical disease problems, and improving overall efficiency of producing pork (Berger et al., 1994b; Dunlop et al., 1994; Straw and Henry, 1994). Hence, restricting the use of feed additives in swine feeds could lead to increased morbidity and mortality rates and to decreased feed efficiency and average daily gain in swine. Together these could increase both the feed and non-feed costs of pork production (Manchanda et al., 1994). Because of the significant financial benefits of using feed additives in food animal production, most producers would want to continue using these additives. Therefore, efforts need to be made to avoid antibiotic and sulfonamide residues in the finished product. Most feed additives have two dosages labeled for use in swine: a low level to enhance growth and a higher level to treat specific diseases (Henry and Upson, 1992; Bennett, 1993; Friendship, 1993; Prescott and Baggot, 1993). These dosages have specific withdrawal times to ensure that pork products reach consumers without illegal residues (NPPC, 1991; Henry and Upson, 1992; Bennett, 1993).

Veterinarians and producers are required to use feed additives in a responsible manner (NPPC, 1991; Kaneene and Miller, 1992; Kunesh and Zimmerman, 1994; Phillips, 1994). Also, the use of feed additives on each farm needs to be continually monitored and evaluated (Henry and Upson, 1992; Straw and Henry, 1994). By describing the extent of use of feed additives in swine feeds it is hoped that practices which are more likely to lead to residues in finished products will be identified. Veterinarians and producers will then be encouraged to change those practices (Kaneene and Miller, 1992; Kelch and New, 1993; Prescott and Baggot, 1993).

The purpose of this study was to describe how frequently feed additives are used in swine feeds at the labeled dose. The second objective was to determine associations between labeled and off-label use of feed additives in swine feeds, and farm size, veterinary consultant use, class of animal, and type of feed additive.

2. Materials and methods

2.1. Source of data

Swine producers voluntarily participated in the USDA-APHIS National Animal Health Monitoring System (NAHMS) National Swine Survey following selection using the multiple-frame sampling technique of the National Agricultural Statistics Service (USDA, 1992; Tubbs et al., 1993). A more detailed description of the study population and selection process is presented elsewhere (USDA, 1992; Tubbs et al., 1993). Although the study lasted 1 year, individual producers were monitored for only 3 months and feed data were collected for only 1 week. Hence the data represent one point in time for each producer. Producers participating in the NAHMS National Swine Survey completed a feed data sheet for each feed used on the farm (NAHMS, 1992). This included information on the class of animals eating the feed, the brand name or the generic equivalents of the feed additives in the ration, and the amount of each product added to the ration. Efforts were made to determine the generic equivalent of each product name.

Feed diaries were kept for each ration used on the farm for 7 consecutive days (NAHMS, 1992). Producers recorded which ration was fed to each class of pigs. The classes were: nursing piglets, nursery pigs (weaned to 39 pounds), grower 1 (40–99 pounds), grower 2 (100–179 pounds), finishing pigs (180 + pounds), lactating sows, gestating sows and gilts, boars, cull sows, and other for those not defined by the producer (NAHMS, 1992). In this study, the animals were classified as growing animals, including nursing, nursery, and grower pigs, marketable animals including finishing pigs and lactating and cull sows, and breeding animals including gestating sows and gilts and boars. Detailed descriptions of the producer questionnaires and the diary cards are presented elsewhere (NAHMS, 1992).

Producers reported the total number of pigs on the farm by class. The farm size was calculated as the sum of the number of replacement gilts not yet bred, sows and gilts gestating, sows nursing piglets, and open sows (NAHMS, 1992).

Table 1
Use of additives in swine feeds by farm size as measured by number of sows, 1989–1991

No. of sows	Total no. of farms	Veterinary consultant	No. of farms with no additive use	No. of farms with only labeled use	No. of farms with off-label use
1–49 [a]	174	Yes	24	62	25
		No	22	29	11
50–99	158	Yes	8	55	58
		No	6	17	14
100–499	324	Yes	15	129	139
		No	4	19	18
500 +	54	Yes	3	20	30
		No	0	0	1

[a] One farm in this category had missing veterinary consultant information, but was using one or more additives in an off-label manner.

Table 2
Rates of labeled use of feed additives by class of pig in the US swine industry, 1989–1991

Class of pig	Number of feeds			% labeled use of additive
	Total	Any additive use	Labeled use of additive	
Nursing	542	412	350	84.95
Starter	1001	812	664	82.00
Grower 1	778	561	437	78.00
Grower 2	738	477	374	78.00
Finisher	607	373	294	79.00
Lactating sow	740	328	197	60.00
Gestating sow	849	194	127	65.00
Boars	588	118	87	74.00
Culls	213	53	42	79.00
Other	67	30	21	70.00
Total	6123	3358	2593	77.00

Table 3
Use of additives in swine feeds in the USA, by class of animal, 1989–1991

Additive	Class [a]	Total use	Labeled use [b]	
		No. of feeds	No. of feeds	%
Apramycin	Growing	226	197	87
	Market	2	0	0
	Breeding	4	0	0
Carbadox	Growing	400	275	69
	Market	5	0	0
	Breeding	5	0	0
Bacitracin	Growing	218	164	75
	Market	159	122	77
	Breeding	18	12	67
Tetracyclines	Growing	1159	906	78
	Market	470	367	78
	Breeding	269	222	83
Penicillin	Growing	376	335	89
	Market	58	50	86
	Breeding	34	26	76
Lincomycin	Growing	110	84	76
	Market	8	5	63
	Breeding	2	0	0
Tylosin	Growing	182	143	79
	Market	69	55	80
	Breeding	13	8	62

[a] Animal classes: growing—creep, nursery, grower 1, grower 2 market; finisher—cull, lactation; breeding—boar, gestation, other.
[b] Labeled use, no greater than the highest recommended dose, no more than one additive in the feed and fed to correct size of animal.

Table 4
Combinations of feed additives fed to immature swine in the study, 1989–1991

Combination	Type of feed								
	Creep		Starter		Grower 1	Grower 2		Finisher	
	No. of feeds	No. of pigs	No. of feeds	No. of pigs	No. of feeds	No. of feeds	No. of pigs [a]	No. of feeds	No. of pigs
Chlortetracycline/ sulfathiazole/ penicillin	26	3239	89	25296	54	18	38528	7	1482
Tylosin/sulfamethazine	8	416	14	6035	17	7	11770	3	137
Chlortetracycline/sulfamethazine/penicillin	35	6239	66	23896	36	16	27154	4	429
Furazolidone/oxytetracycline/arsanilic acid	44	5965	85	31924	43	13	32698	5	1,069
Oxytetracycline/neomycin	27	4811	47	17879	14	7	7433	8	2,006
Penicillin/streptomycin	0	–	3	1011	6	4	4363	4	910
Carbadox/pyrantel tartrate	0	–	5	159	0	0	–	0	–
Furazolidone/oxytetracycline	1	28	1	195	0	0	–	0	–

[a] Total of grower 1 and grower 2.

Table 5
Combinations of feed additives fed to adult swine in this study, 1989–1991

Combination	Type of feed							
	Lactation		Gestation		Boar		Cull	
	No. of feeds	No. of pigs	No. of feeds	No. of pigs	No. of feeds	No. of pigs	No. feeds	No. pigs [a]
Chlortetracycline/sulfathiazole/penicillin	18	517	9	1280	6	58	0	0
Tylosin/sulfamethazine	2	87	1	433	0	0	0	0
Chlortetracycline/sulfamethazine/penicillin	13	278	6	1121	4	25	3	20
Furazolidone/oxytetracycline/arsanilic acid	49	864	21	2721	6	55	2	0
Oxytetracycline/neomycin	56	1049	19	3184	5	49	3	13
Penicillin/streptomycin	4	118	2	146	0	0	0	0
Furazolidone/oxytetracycline	5	78	2	193	0	0	0	0

[a] This number may be 0, even if number of feeds is > 0, if the farm regularly uses this additive in this stage of animal, but did not have any of that stage of animal when the inventory was taken.

The dependent variables in the analyses included producer-reported feed additives used in each ration and the concentration of feed additive per ton of complete feed (NAHMS, 1992). For this study, ration refers to a specific diet used by the producer

Table 6
Feed additives used in creep and starter pig rations in this study, 1989–1991

Additive	Dose less than growth promotion level [a,b]	*n*	Dose at growth promotion level [a,b]	*n*	Dose at treatment level [a]	*n*	Dose greater than treatment level [a]	*n*
Apramycin [c,d]	< 150	3820	N/A	0	150	172	> 150	11
Arsanilic acid	< 45	0	45–90	4	225–360	0	> 360	0
Bacitracin	< 10	0	10–40	2	41–250	3	> 250	0
Bambermycin [e]	< 2	0	2–4	1	N/A	0	> 4	0
Carbadox	< 10	7	10–25	16	26–50	225	> 50	41
Chlortetracycline	< 10	1	10–50	6	51–400	79	> 400	11
Furazolidone	< 100	2	100–200	14	201–300	3	> 300	1
Lincomycin	< 20	1	20–40	14	41–200	65	> 200	5
Neomycin [c]	< 70	0	N/A	0	70–140	13	> 140	14
Oxytetracycline	< 7.5	0	7.5–50	1	51–150	33	> 150	19
Penicillin [e]	< 10	0	10–50	7	N/A	0	> 50	0
Pyrantel tartrate	< 96	5	96–110	24	200–800	2	> 800	3
Sulfamethazine [e]	< 100	0	100	2	N/A	0	> 100	2
Tiamulin	< 10	0	10	0	35	2	> 35	0
Tylosin	< 20	1	20–40	3	41–100	11	> 100	2

[a] Amount of additive (g ton^{-1}).
[b] Dose represents that used for growth promotion or to prevent disease.
[c] No labeled prevention or growth promotion dose for swine.
[d] Not labeled for use in finisher pigs.
[e] No labeled treatment dose for swine.

whereas feed refers to the diet fed to a class of animal. Therefore a ration represents two feeds if it is fed to two different classes of animals. The ration was assigned to each class of animal using the feed consumption information. If one class of pigs received two rations, then there were two feeds assigned to that class of pig. If the same feed additive was fed to two classes of animals on one farm, it was listed as two uses. Feed additive inclusion was categorized as either labeled or off-label use. Labeled use included feed additives at a concentration less than or equal to the highest recommended treatment dose listed in the *Compendium of Veterinary Products* (Bennett, 1993), only one feed additive per ration unless used in labeled combinations, and used in the classes of animals for which it was labeled (Tables 1–3) (NPPC, 1991; Henry and Upson, 1992; Prescott and Baggot, 1993; Bennett, 1993; Dunlop et al., 1994; Straw and Henry, 1994). Feed use classified as off-label described either the use of a single feed additive higher than above the level labeled for treatment or multiple feed additives in one feed in combinations other than labeled combinations, or feed additives fed to a class of animal other than the recommended classes (NPPC, 1991; Paige, 1994).

Table 7
Feed additives used in grower swine rations in this study, 1989–1991

Additive	Dose less than growth promotion level [a,b]	*n*	Dose at growth promotion level [a,b]	*n*	Dose at treatment level [a]	*n*	Dose greater than treatment level [a]	*n*
Apramycin [c,d]	< 150	1	N/A	0	150	2	> 150	2
Arsanilic acid	< 45	0	45–90	3	225–360	0	> 360	0
Bacitracin	< 10	6	10–40	100	41–250	100	> 250	8
Bambermycin [d]	< 2	0	2–4	3	N/A	0	> 4	0
Carbadox [f]	< 10	2	10–25	4	26–50	56 [d]	> 50	15
Chlortetracyclin	< 10	5	10–50	65	51–400	214	> 400	37
Furazolidone	< 100	1	100–200	5	201–300	1	> 300	2
Hygromycin B [d]	< 12	0	12	2	N/A	0	> 12	0
Lincomycin	< 20	6	20–40	9	41–200	8	> 200	2
Neomycin [c]	< 70	0	N/A	0	70–140	5	> 140	7
Oxytetracycline	< 7.5	2	7.5–50	6	51–150	24	> 150	33
Penicillin [d]	< 10	0	10–50	3	N/A	0	> 50	4
Pyrantel tartrate	< 96	0	96–100	11	800	0	> 800	1
Sulfamethazine [d]	< 100	0	100	0	N/A	0	> 100	1
Tiamulin	< 10	1	10	1	35	3	> 35	4
Tylosin	< 20	10	20–40	50	41–100	39	> 100	18
Virginiamycin	< 5	0	5–10	9	11–100	5	> 100	0

[a] Amount of additive (g ton^{-1}).
[b] Dose represents that used for growth promotion or to prevent disease.
[c] No labeled prevention or growth promotion dose for swine.
[d] Not labeled for use in grower pigs.
[e] No labeled treatment dose for swine.
[f] Not labeled for use in pigs > 75 lb, carbadox was included in six feeds fed to growers over 99 lb.

2.2. Statistical analysis

Cochran–Mantel–Haenszel chi-square tests were used to compare the prevalence of labeled use of feed additives by farm size stratifying for veterinary use and veterinary use stratifying for farm size (Kleinbaum et al., 1982). Cochran–Mantel–Haenszel chi-square tests were used to compare the prevalence of labeled use of feed additives by class of animal after stratifying for type of feed additive and type of feed additive after stratifying for class of animal. Descriptive statistics and statistical tests were done using the Statistical Analysis System for Personal Computers (PC/SAS) (SAS Institute Inc., 1988).

3. Results

A total of 1661 producers initially agreed to participate in the USDA-APHIS NAHMS National Swine Survey; however, only 710 producers actually completed the entire survey (USDA, 1992; Tubbs et al., 1993) (Table 1). On 11.5% (82/710) of the farms there were no feed additives added to feeds and 67 farms only listed labeled combinations of feed additives. Of the remaining 561 farms using known individual feed additives, 264 (47%) farms used all of the feed additives in the labeled manner.

The 710 farms in the data set had a total of 3750 separate rations. Of these, 1484 did not contain a feed additive, 1369 included one feed additive and 897 contained more

Table 8
Feed additives used in finisher pig rations in this study, 1989–1991

Additive	Dose less than growth promotion level [a,b]	*n*	Dose at growth promotion level [a,b]	*n*	Dose at treatment level [a]	*n*	Dose greater than treatment level [a]	*n*
Apramycin [c,d]	< 150	0	N/A	0	150	0	> 150	1
Arsanilic acid	< 45	0	45–90	1	225–360	0	> 360	0
bacitracin	< 10	3	10–40	62	41–250	62	> 250	8
Bambermycin [e]	< 2	0	2–4	1	N/A	0	> 4	0
Chlortetracycli	< 10	2	10–50	33	51–400	90	> 400	14
Furazolidone	< 100	0	100–200	1	201–300	1	> 300	0
Lincomycin	< 20	3	20–40	2	41–200	1	> 200	0
Neomycin [c]	< 70	0	N/A	0	70–140	1	> 140	0
Oxytetracycline	< 7.5	0	7.5–50	3	51–150	8	> 150	11
Penicillin	< 10	0	10–50	1	N/A	0	> 50	1
Pyrantel	< 96	0	96	0	800	0	> 800	1
Tiamulin	< 10	1	10	1	35	1	> 35	3
Tylosin	< 10	1	10–40	31	41–100	19	> 100	4
Virginiamycin	< 5	0	5–10	8	100	1	> 100	1

[a] Amount of additive (g ton^{-1}).
[b] Dose represents that used for growth promotion or to prevent disease.
[c] No labeled prevention or growth promotion dose for swine.
[d] Not labeled for use in finisher pigs.
[e] No labeled treatment dose for swine.

than one feed additive. Of the rations with multiple additives, 75% (673/897) contained labeled combinations of feed additives (Tables 4 and 5). In these 673 rations with combinations, the amount of each individual feed additive used could not be determined. The amount recorded could have referred to all feed additives together or just one of the feed additives. For the analyses it was assumed that these combination products were used according to labeled use. However, six rations included two groups of combination products and these rations were deemed off-label use. There were 32 rations where the generic equivalent to the proprietary feed additive listed was unknown. These rations were assumed to contain the labeled amount of the feed additive. There were 468 rations with off-label uses of feed additives. Hence, farms that used off-label feed additives did so in an average of 1.58 rations (468/297).

The 3750 rations were often fed to more than one class of pig resulting in a total of 6123 feeds. Forty-five percent (2765/6123) contained no feed additive (Table 2). The use of feeds with no feed additives was higher in adult animals (77.3%) than in either marketable animals (51.7%) or growing animals (26.1%) ($P < 0.0001$). However, marketable animals were 1.9 times more likely to be fed diets with no feed additives than growing animals.

Of the 3358 feeds with feed additives, 77% (2593) contained feed additives used in the labeled manner (Table 2). The prevalence of labeled additive use was greater than

Table 9
Feed additives used in lactating sow and cull sow rations in this study, 1989–1991

Additive	Dose less than growth promotion level [a,b]	*n*	Dose at growth promotion level [a,b]	*n*	Dose at treatment level [a]	*n*	Dose greater than treatment level [a]	*n*
Amprolium [c]	N/A	0	90	1	N/A	0	N/A	0
Apramycin [d]	< 150	0	N/A	0	150	1	> 150	0
Bacitracin	< 10	1	10–40	11	41–250	12	> 250	0
Carbadox [e]	< 10	0	10–25	1	26–50	4	> 50	0
Chlortetracyclin	< 10	4	10–50	17	51–400	91	> 400	12
Decoquinate [c]	< 50	0	50–100	3	N/A	0	> 100	1
Furazolidone [e]	< 150	20	150	13	N/A	0	> 150	17
Lincomycin [f]	< 20	2	20–40	0	41–200	0	> 200	0
Monensin [c]	N/A	0	N/A	0	N/A	0	N/A	1
Neomycin [d]	< 70	2	N/A	0	70–140	1	> 140	3
Oxytetracycline	< 7.5	0	7.5–50	2	51–150	7	> 150	10
Penicillin [e]	< 10	0	10–50	1	N/A	0	> 50	2
Pyrantel	< 96	0	96	2	800	0	> 800	0
Sulfamethazine	< 100	0	100	0	N/A	0	> 100	1
Tylosin	< 10	0	10–40	4	41–100	4	> 100	1
Virginiamycin	< 5	0	5–10	0	11–100	4	> 100	0

[a] Amount of additive (g ton^{-1}).
[b] Dose represents that used for growth promotion or to prevent disease.
[c] Not labeled for use in swine.
[d] No labeled prevention or growth promotion dose for swine.
[e] No labeled treatment dose for adult swine.
[f] Not labeled for swine weighing more than 250 lb.

Table 10
Feed additives used in sow gestation and boar rations in this study, 1989–1991

Additive	Dose less than growth promotion level [a,b]	n	Dose at growth promotion level [a,b]	n	Dose at treatment level [a]	n	Dose greater than treatment level [a]	n
Apramycin [c]	< 150	0	N/A	0	150	2	> 150	0
Arsanilic acid	< 45	0	45–90	4	225–360	1	> 360	2
Bacitracin	< 10	0	10–40	8	41–250	10	> 250	0
Carbadox [d]	< 10	0	10–25	1	26–50	4	> 50	0
Chlortetracyclin	< 10	4	10–50	20	51–400	138	> 400	16
Decoquinate [e]	< 4356	0	4356	1	N/A	0	> 4356	0
Furazolidone [d]	< 150	8	150	3	N/A	0	> 150	3
Lincomycin [f]	< 20	0	20–40	0	41–200	2	> 200	0
Monensin [e]	N/A	0	N/A	0	N/A	0	N/A	1
Neomycin [c]	< 70	0	N/A	0	70–140	2	> 140	3
Oxytetracycline	< 7.5	0	7.5–150	10	151–500	9	> 500	1
Penicillin [d]	< 10	0	10–50	2	N/A	0	> 50	5
Pyrantel	< 96	0	96	0	800	0	> 800	2
Roxarsone	< 22	0	22–34	2	35–182	0	> 182	0
Tylosin	< 10	2	10–40	5	41–100	2	> 100	3

[a] Amount of additive (g ton^{-1}).
[b] Dose represents that used for growth promotion or to prevent disease.
[c] No labeled prevention or growth promotion dose for swine.
[d] No labeled treatment dose for adult swine.
[e] Not labeled for use in swine.
[f] Not labeled for swine weighing more than 250 lb.
[g] Highest labeled treatment dose in boars is 150 g ton^{-1}. One producer was feeding a higher dose to boars.

60% in all classes of pigs. Penicillin was fed according to the labeled use the most often, followed by apramycin, bacitracin, tetracyclines, lincomycin, and tylosin (Table 3). Carbadox had the highest prevalence of off-label use.

Of the 699 feeds that included feed additives in an off-label manner, 57% (399/699) contained additives at greater than the recommended concentration or were fed to an incorrect class of pig. Fifty-six percent (388/699) of the feeds had off-label combinations of additives. There were 88 feeds with both combinations of additives and either a higher concentration than the labeled amount or they were fed to the wrong class of pig (Tables 6–10). Three feed additives listed were not labeled for use in swine. These were amprolium, decoquinate and monensin.

Large and intermediate farms were more likely to use feed additives in the rations than small farms (Table 1) ($P < 0.001$). Of those farms using feed additives, small farms were 7.7 times more likely to use all feed additives in the labeled manner than intermediate and large farms ($P < 0.0001$).

Of the 710 farms, 65.2% (463/710) used a veterinarian and 80% (568/710) used a non-veterinary consultant for advice on disease, management, and/or nutrition. After controlling for farm size, producers who did not use a veterinary consultant were 2.1 times more likely to use feeds without feed additives ($P < 0.01$) than producers who

used a veterinarian. The use of a veterinarian was associated with an increased use of tetracyclines ($P < 0.001$, RR = 1.2), carbadox ($P < 0.03$, RR = 1.1), apramycin ($P < 0.05$, RR = 1.1), tylosin ($P < 0.003$, RR = 1.2), and bacitracin ($P < 0.003$, RR = 1.1).

4. Discussion

Typically feed additives are added to swine diets at therapeutic levels to treat specific diseases or to prevent disease, and at subtherapeutic levels to increase growth rate and feed efficiency (Table 4) (Jukes, 1986; Berger et al., 1994b; Dunlop et al., 1994; Straw and Henry, 1994). Some producers with chronic disease problems in swine may choose to use feed additives within one age group of animals for extended periods of time to prevent clinical signs of a specific disease (Dunlop et al., 1994). Of the 710 farms in the data set, 11.5% (82/710) did not use feed additives in any feeds (Table 1). There were 6123 feeds (pig–class–ration combinations) documented. Forty-five percent of these feeds contained no feed additive (Table 2).

The reasons producers and veterinarians must be cognizant of the use of feed additives in swine include: the possibility of feed additive residues, inapparent carriers of antimicrobial drug-resistant bacteria that may cause zoonotic diseases, and the exchange of plasmids from antibiotic-resistant bacteria in swine to human pathogens making the human pathogens antibiotic-resistant (Moats, 1986; Franco et al., 1990; Gustafson, 1991; Sundlof, 1993; Beran, 1994; Waltner-Toews and McEwen, 1994). The terminology label and off-label used in this study referred to whether or not the feed additives were fed to pigs as directed in the *Compendium of Veterinary Products* (Bennett, 1993). In the USA, off-labeled use is illegal. However, the use of feed additives in an off-labeled manner does not necessarily imply that there were antibiotic or sulfonamides in the pork products at time of slaughter and should not be equated with residues.

Feed additives used in a manner other than labeled use are of most concern in animals that are almost ready to be marketed. Of those producers using feed additives in feeds, 52.7% (331/628) used all of the feed additives in the labeled manner. Of the 3358 age–feed combinations with feed additives, 77.2% included feed additives at the labeled dosages. The labeled use of feed additives was more common in growing animals (80.7%) than in market (70.7%) or adult animals (68.7%; Table 2) ($P < 0.01$). Both finisher pigs and lactating sows were included in the market animal category. Often sows are sold directly after weaning their litters; hence, they are the most likely adult animal to become part of the food chain (Meeker, 1989). In this sample of farms, sows were kept an average of 3.6 (± 0.1) days from weaning to culling (NAHMS, 1992). Farms that keep sows after weaning, prior to culling, rarely have a specific cull-sow feed. Only four farms (4/710) used a specific feed for culled sows.

After controlling for the use of veterinarians, farms with less than 50 sows were 4.3 times more likely to use feeds without feed additives than larger farms (Table 1) ($P < 0.0001$). A similar pattern of increased use by herd size was found in both dairy and beef cattle (Kaneene and Miller, 1992; Kelch and New, 1993). Small farms using

feed additives were 7.7 times more likely to use all feed additives in the labeled manner than intermediate or large farms ($P < 0.0001$).

After controlling for herd size, producers who used a veterinary consultant were 2.1 times more likely to use feeds with feed additives ($P < 0.0001$). Producers using veterinarians were more likely to use tetracyclines, carbadox, apramycin, tylosin, and bacitracin than producers not using consultants. In a similar study of feed additive use in dairy cattle, veterinary consultation was associated with an increased use of injectable tetracyclines (Kaneene and Miller, 1992). Consultants may encourage producers to use feed additives in immature swine feeds because of the expected production benefits. However, the increased prevalence was seen in all classes of animals. Producers who have disease problems may be more likely to use a consultant and use feed additives in the feed. Therefore, the relationship may be due to the common factor of disease and may or may not imply that veterinarians promote the use of feed additives. Although there was no association between the labeled use of feed additives and the use of a veterinarian, veterinarians should be encouraged to promote the labeled use of feed additives (Cordle, 1989; FDA, 1994; Waltner-Toews and McEwen, 1994). The National Pork Producers Council has established the Pork Quality Assurance (PQA) program to educate producers about the labeled use of feed additives and what steps to take to avoid residues (Meeker, 1989; NPPC, 1991). This program provides an opportunity for veterinarians to work with producers toward a common goal. Some of the recommendations of the program include: annual review of all feed additive use by the producer and the veterinarian, education of all personnel working on the farm regarding the appropriate use of each feed additive and steps to take to avoid residues, proper feed mixing protocols, and keeping comprehensive records of which animals were treated. The data for this study were collected from 1989 to 1991, when the PQA program was beginning. By the end of 1991 there were only 193 pork producers certified at level III of the PQA program (P. Sundberg, 1994, personal communication). At the end of 1994 there were 11 562 producers certified at level III. It is anticipated that the frequency of labeled use of feed additives in the US swine industry will have increased because of the educational efforts of the veterinarians and producers through the PQA program (Cordle, 1989). However, a second survey will need to be conducted to measure this trend.

The results of this study pertain specifically to this sample of farms. Although a random sample of farms was selected, the results may be biased because the participants were volunteers and only 43% of the cooperators completed the study. Another weakness of this study is the uncertain validity of producer observations. There may be a bias due to inaccurate knowledge of the levels and types of the feed additives in the feed. Probable examples include sulfamethazine and neomycin. These feed additives are only available as feed additives in combination with other feed additives but were designated as being used alone (Paige, 1994). These producers might have been using these feed additives in the correct formulations but did not record them as such. Producers who indicated that they were using either neomycin or sulfamethazine as single feed additives were identified as using an off-label feed additive. It is the responsibility of the producer to be aware of the feed additives used in the feeds on their farm (NPPC, 1991).

Restricting the use of antibiotics and sulfonamides in swine feeds is likely to increase

the morbidity and mortality rates in swine (Meeker, 1989) and decrease feed efficiency, which would cause an increase in both feed and non-feed costs of pork production (Manchanda et al., 1994). Because of the financial benefits of continued use of feed additives in food animal production, efforts must be made to use these products in a responsible manner.

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